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Research Article

## 3D Printing for Garments Production: An Exploratory Study

Agita Valtas and Danmei Sun\*

### Abstract

This paper explores the possibility of introducing 3D printed parts into commercial garment production. The research investigates the cost and time needed to create 3D printed components for garment construction at the sample stage and provides an example of garment construction techniques. This research is completed in order to investigate whether such manufacturing method would benefit the garment manufacturer and to define areas need to be improved for 3D printing that would possibly become an essential part of mass manufacture in the fashion industry. By completing the garment and analyzing the process it has been proved that it is possible to partially 3D-print garment that can serve several benefits.

### Keywords

3D printing; Commercial garment; Cost; Speed; Limitations; Implications

### Introduction

Since three-dimensional (3D) printing was first introduced it has been widely used in many manufacturing industries from medicine to transportation, and has even slowly become popular among fans of Computer Aided Design (CAD) that can now own and use a 3D printer at their homes. 3D printing is a way of manufacture where material is laid down layer by layer to create 3D objects. These objects are created from a digital file containing three-dimensional data extruded by printer, which can employ a wide range of materials and techniques [1].

Using CAD programs, engineers can develop a 3D model of the object to be generated in a computer. The developed model is then translated into a series of two-dimensional (2D) "slices" of the object and then informs the printer exactly where to solidify the starting material on each successive slice [2].

Because of the process of 3D printing, it allows to avoid disadvantages of conventional manufacturing, one of them being the lack of flexibility. It can be noted that because of the whole unit is built independently, it requires to get changed easily to accommodate the enhancements or change of fashion. Moreover, the manufacturing preparation process is simple because it needs fewer stages. Not only is it good for producing prototypes or samples in small scale, but also in mass manufacturing, because of the size, colour and shape of

the generated 3D object can be easily changed in computer without adding additional cost [3].

Most of the current commercial available 3D printers have limited printing area. For printing 3D garments FDM, SLS and PolyJet are often used due to the comfortability of the printed items they can print. Light weight polymers or polymer composites are the main materials used as printing materials allowing flexibility of the printed items [4].

It is able to build objects by layers to eliminate unnecessary production of small pieces, but instead 3D object printing can be produced in one setting, cut time not only depends on the production, but also the assembly. This leads to the understanding that if fewer pieces need to be made, it allows to reduce the amount of waste. This would be very useful to the garment manufacture industry as fabric waste is one of the biggest issues while mass manufacturing brands to avoid any considerations of reducing seam allowances, pattern sizing, changing pattern lay plans and many more. 50% of the final cost of a garment is made up from a cost of the material that has been used in production [5], therefore, if it is possible to eliminate the cutting process altogether, it will make zero material waste possible.

Furthermore, being a portable way of manufacturing, 3D printing therefore is independent on where it is located and allows taking the production closer to the market, which automatically reduces the global carbon footprint of the supply chain [6]. In the past couple of years 3D printed garments have been presented in fashion shows [7-10]. One of them was the high-fashion Dutch designer Iris Van Herpen, who produced a full-scaled garment using 3D printing.

Although in recent years, some 3D printed garments have appeared on the cat walks, however there are limited publications in 3D printing of garments and fashion. Yap [4] reviewed the current 3D additive printing techniques, printing materials, basic design procedures and fabrication of 3D printed fashion products, as well as finishing technology. Sabantina et al. [11] reported the mechanical and geometrical properties of multi-material systems through combining 3D printed PLA with textile structures. 3D printing in fashion is still in its early stage and if it were to be soon seen on the high-street, it would probably be introduced through high-end brands that create their collections not only to sell the product, but use it as a marketing tool. A 3D printed garment or part of a garment that is created with 3D printers has not been widely manufactured in fashion industry. A product like this would not be safe to manufacture in mass production as it is only speculated that it can reduce cost and manufacture time, but has never been tried in garment manufacture.

The aim of this project is to produce commercial and wearable garment and by doing so to determine if it is comparable to garment made by conventional method. Garment made like such can offer similar functionalities and characteristics as fabric panels and fit into the market sector of the label, but it is also important to take into consideration the time and cost of manufacture, to determine whether this way of manufacturing can be beneficial to garment and fashion industry.

### Methodology

In this research MakerBot Replicator 2X shown in Figure 1, was

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used for manufacturing 3D printed component of the garment. The MakerBot uses the FDM technology; it has built-in slicing software called Makerbot Makeware. It has the following specifications:

Build Volume: 24.6 L × 15.2 W × 15.5 H cm;

Layer Resolution: 100 microns;

Positioning Precision: XY: 11 microns; Z: 2.5 microns;

Input Format: STL, OBJ, Thing.

A wide selection of filament types is available for commercial use and manufacturing; a relatively recent development provided filament materials with flexible characteristics, although it still cannot provide the same flexibility as silk filament for example, but they allow the finished garment to move much more easily with good flexibility. Filament used in manufacturing parts of garment for this project is Filaflex (£59/kg), a TPE based polyurethane with additives. The software used for design the three-dimensional part of the garment is blender – a very useful software for modeling, animation and rendering source.

Before printed into garment panels small samples were manufactured to test the compatibility with the printer and the flexible filament. Through this process the ready-made textiles were picked due to speed of printing.

## Results and Discussion

### Design and 3D printing

The process of 3D printing starts with the design file that needs to be comparable with the software built in the 3D printer for manufacture. The software gives directions to the components to be printed with what needs to be completed [12].

Due to the small area available for printing of the most widely used commercial printers, it is almost impossible to print a whole garment in one setting. Therefore, the garment printing needs to be done in parts, then assembled together where needed. These parts will be created through segmentation of the design.

There are many possibilities for the assembly of the parts such as bonding with adhesive and melting together, or through special physical joining mechanisms such as hooks, screws etc. [4]. In this research bond by melting together technique was used as the printing material is meltable.

The printed garment part is composed of three main parts that are front, shoulder and back; they are printed in the original and mirror dimensions. The front panel of the print uses 26.98 grams of the polymer material and takes 2 hours and 12 minutes to print (Figure 2a), the shoulder panel uses 16.45 grams of the filament and takes 1 hour and 25 minutes to print (Figure 2b) and the back panel uses 30.24 grams and takes 2 hours and 33 minutes to be printed out (Figure 2c).

The total material usage of top part of the dress is 147.34 grams and the total print time is 12 hours 36 minutes, with material cost of £8.70. So, the material cost does not increase dramatically, due to the pattern chosen for the garment. The period of printing can be reduced by printing the full scale garment in one setting for mass production.

As 3D printing garments were attempted by other researchers, but not in cohesion with fabric, no standard is sent for seam construction technique. Initially, the parts were to be constructed together by the classic means of sewing, but when trialed, it was realized that due

to printed panel texture, such action would not be possible. As an alternative, it was decided to neaten the edges of fabric seams and melt the 3D printed textile onto the fabric, which has been proved much better seam construction aesthetically. Such seam construction technique was used in the garment production.

It needs to be mentioned that even though the design of a 3D printable object is important, a more crucial part of it is the final stage of re-assuring the file compatible to be printed. Lipson and Kurman [12] noted that quite frequently when the design file is faulty it slows down the manufacturing process massively. The file format used most frequently in 3D printing is STL, which has been one of the formats used the most by the industry, has been proved not always able to keep up with the advanced printing technology and design software as a whole.

After a design file has been converted to STL format, it “wraps” the design object’s digital “shape” inside a virtual surface, called a mesh that is made up of hundreds and thousands of interlocked polygons. Each interlocked polygon is frequently used in the surface mesh holding information about an object’s shape [12].

The garment part was created using a pattern object, increasing the width of the outline and extracting it into Blender where it will be formed into a 3D printable garment panel. The panel was separated in six pieces due to the limited printing area, allowing a melting allowance around the piece.

As this garment part is relatively thicker, it takes a longer printing time because the printer needs to travel longer more, in order to fill all the layers. The printing process is shown in Figure 3. Although the garment parts are printed automatically once the demand to print has been made, it needs to be paid attention throughout the whole printing process, this mainly because the extruder stops extruding the filament occasionally due to blockage. If there is any blockage happens the production process has to be stopped and restarted again. After several trials and error correction processes it was found that by increasing the extruding temperature from 230°C to 250°C and reducing the printing speed, the problem can be resolved to get the printing task completed in one go.

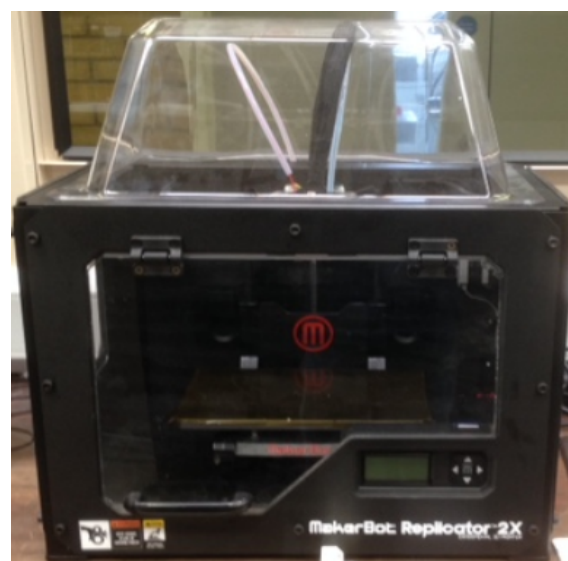


Figure 1: MakerBot Replicator 2X.

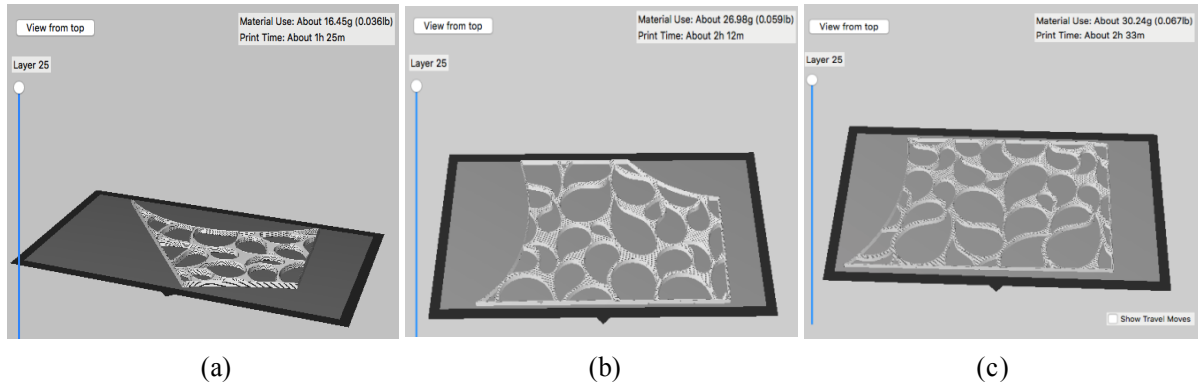


Figure 2: Front, shoulder and back panel in computer design.

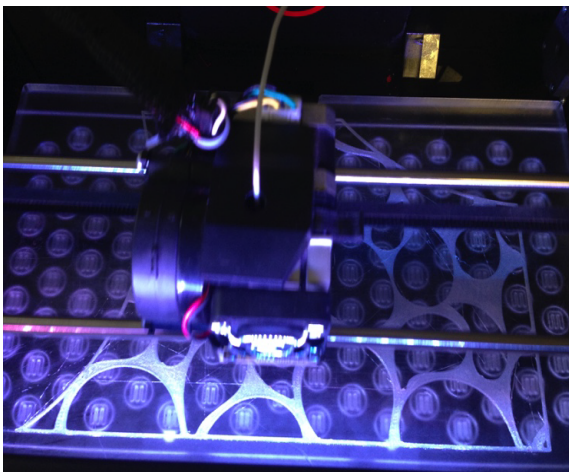


Figure 3: Panel printing.



Figure 4: Whole garment with the top part made by 3D printing.

When the printing process was finished, the panel pieces were melted together and added on the fabric piece, where the edges was neaten by a four-thread overlock.

Figure 4 shows the 3D printed part as a panel that curves around body for neckline and armholes and is able to hold a bottom part of a garment. It shows that the designed is strong enough to withstand the weight of the long length of the lower part of the garment.

The way garment was created for this research project does not really reflect the processes that would be implemented in industry settings where big volumes of garments are produced, therefore, it is not possible to realize a mass manufacture time and cost level for the product, but it gives an insight of estimated costs and looks at the product at the sample stage of manufacturing.

### Limitations of 3D textile and garment printing

As a novel way of manufacturing technique, 3D printing of textiles and garments has some disadvantages. This is mainly because 3D printing is strongly focused on other areas of manufacture and has not really been advanced to the standards for mass manufacture, whether it is the input filament itself or the design software. Its main aim is not for garment manufacture till now.

One of the main limitations for 3D garment printing is the commercial available materials. Due to the drapability stretchability and comfortability requirement of a garment, the filament material used for 3D garment printing needs to be flexible and absorbent. However the filaments for 3D printing are far from the above mentioned property requirement. The printed 3D garments are fairly strong and water-resistant and they cannot be treated like many popular materials we use daily such as cotton and silk. Textiles printed with these filaments cannot be machine washed, ironed or pressed. They are lack in absorbency and cannot be sewn. When purchasing garments people see values of garments made of 100% wool, linen, silk which provide comfort to wearer. Wearing a rubber like garment for daily wear would not be a good choice. Rubber like material is seen to be used for footwear and accessories. Therefore to produce 3D printed garment there is demand to develop new filaments to meet property requirements of textiles.

As 3D printing was not necessarily invented for garment manufacture initially, a lot of the available software does not allow the technical means needed when creating a 3D file for a garment. While a lot of programs nowadays allow visualizing garments on a 3D human body, none of them currently have the ability to design onto



a human body and extract the design as a ready printable STL file. In many cases, the designing process lengthy and tricky, and limited to the availabilities of the printer. When completing this project, the majority of the time was spent designing on Blender and fixing the file to prepare it for printing. An obvious limitation during the project was the lack of skill of the designer of these files, but even with the help of skilled professionals, it faced a lot of issues, which would not be welcome at a mass manufacturing level.

## Conclusions, Industrial Implications and Future Research

The research proved that it is possible to create garment that is able to feature 3D printing leading to many potential impacts. It is noted that this is more at the conceptual stage rather than at an actual stage of manufacture that can completely overtake the manufacturing that is known today. By carrying out the research several points were made towards the fact that implementing 3D printing into manufacturing chain can benefit the industry within several sectors.

- By enabling to print the exact size of the object that is needed for the final product, it completely eliminates any waste whatsoever that would occur in situations when pieces are cut from a fabric lay. Therefore this not only can decrease the cost of manufacture, but also is beneficial to the environment by producing exactly what is needed and unnecessary misuse of materials is eliminated.
- It shortens the steps that need to be taken during production. With 3D printing, the fabric laying, cutting, assembling and sewing are integrated into one step, where just by creating a design file to be printed.
- The product made is of higher quality than the product made when sewing, because 3D garment printing eliminated from occasional human error in traditional garment manufacture.
- 3D garment printing technique is beneficial to mass customization [13,14] there is almost no design limitation.
- The access to 3D printing technology still involves high investment costs and time during the production of the 3D elements. These costs are eventually passed on to the final product.
- Future research in 3D garment printing should look at the development of novel filament materials, relationship between pattern/element selection and flexibility of the printed garment, etc.

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